Remarks

Claims 1 – 20 were original in the application. Claims 1 – 20 have been amended. Therefore, claims 1 – 20 as amended are submitted for examination on the merits.

Rejection Pursuant to 35 USC 112

Claims 1 - 20 were rejected as being indefinite. Regarding claim 1, the Examiner asserted that the phrase "nanocavity array", " photonic crystal", "lithographically formed", and "predetermined spectral response" is unclear in that the Examiner was uncertain what is a "nanocavity" means. The Examiner further contended that claim did not recite laser structure, so therefore it could not define a nanocavity. Finally, the Examiner contended that it was not clear how to lithographically form and obtain a predetermined spectral response of each nanocavity.

The nature of the Examiner's objection is not clearly understood in that it appears the Examiner is contending that the terms, "nanocavity array", " photonic crystal", "lithographically formed", and "predetermined spectral response" do not have a definite meaning to one with ordinary skill in the art. The applicants respectfully disagree in that these are the words and phrases by which the relevant technology is named and described. It would be difficult to claim the invention other than in the terms by which its elements are understood in the art. However, it is appreciated that claim 1 as originally submitted may have not been as clearly worded as could be desired. Claim 1 is amended to present the

originally claimed invention with clarity.

"Nanocavity" is a term known in the scientific literature and is particularly shown throughout the application as a defect in an array of holes which have been lithographically formed in a photonic crystal. The holes form a regular array, except where they have been differently arranged according to the invention. This change in the regularity of the pattern of holes can be called a defect in that pattern, although it is intentionally created. The area of the defect will form an optical cavity in which light may resonant as in a laser cavity. The irregularity will cause the light propagating in the photonic crystal to be reflected and refracted in the vicinity of the defect, hence it is an optical cavity with nanometer dimensions or a nanocavity. This is illustrated in drawings and microphotographs filed with the application, namely Figs. 1a – 2b, and 7a – 9 and the corresponding text in the specification. A casual search of the internet will reveal common usage of the term, "nanocavity" including in the context of lasers. **Painter** cited as the main reference by the Examiner is a prior article from some of the present applicants and describes in detail the fabrication of a single defect nanocavity in terms consistent with those used here, as is clearly understood by the Examiner.

For example, it is stated beginning at page 7, line 6, of the specification

"Fabrication of optical structures has evolved to a precision which allows us to control light within etched nanostructures. Fig. 2a shows a multiwavelength laser array of elements 10. Each element 10 is comprised of a photonic array 11 shown in the enlargement of Fig. 2b in which an array 11 of holes 12 are formed with a single center defect 14 or absence of a hole 12. For example, **subwavelength nano-optic cavities** can be used for efficient and flexible control over both emission wavelength and frequency. Similarly, nanofabricated optical waveguides can be used for efficient coupling of light between devices.

This new capability allows the reduction of the size of optical components and leads to their integration in large numbers, much in the same way as electronic components have been integrated for improved functionality to form microchips. As **high-Q optical and electronic cavity sizes** approach a cubic half-wavelength, the spatial and spectral densities (both electronic and optical) increase to a point where the light-matter coupling becomes so strong that spontaneous emission is replaced by the coherent exchange of energy between the two systems." (emphasis added)

The term "photonic crystal", is similar well known in the scientific literature and refers to crystalline material, typically semiconductors, in which a photonic device may be fabricated typically be defining a plurality of holes in the material having a diameter of the order of the wavelength or less of the light transmitted in the material. A search of the USPTO internet patent collection list at least 130 issued patents which use the term "photonic crystal". The term is also well established in the scientific literature. There are a number of books available at amazon.com including one entitled, "**Photonic Crystals**" by John D. Joannopoulos, Robert D. Meade, and Joshua N. Winn published by Princeton University Press 1995, which is generally directed to a general science readership.

The phrase "lithographically formed" in referring to the nanocavity means that the array of holes is laid out by means of lithographic processes well known in the art of semiconductor manufacturing by which holes in semiconductor materials can be formed. The number of scientific and patent references to "lithographically formed" structures is legion and overwhelming. The Examiner may wish for example to begin by reviewing **Liu , et al.,** *"Photonic Crystal Formed By Laser Machining And Having Holes With Sub-Wavelength Pitch,"*

United States Patent 6,580,547 (2003) and work backwards from that reference.

The phrase "predetermined spectral response" refers to the interaction between light and the nanocavity defined according to the invention in the array of holes in the photonic crystal. The holes cause the light to be refracted in the crystal and the nature of the optical interaction is wavelength dependent. Hence, a nanocavity will have a wavelength dependent interaction with the light traveling through it, or a "spectral response". The nature of the spectral response is determined by the invention according to the size and type of array defect comprises the nanocavity, i.e. the particular array and arrangement of holes which define the nanocavity.

In regard to claims 5 – 11 the Examiner contended that: the phrases, "a laser array", is indefinite because it is unclear what is "a laser array", and the claim fails to recite the structure of a laser array; "a detector array" is indefinite and the claim fails to recite the structure of a detector array; "array is an all optical gate" is indefinite and claim fails to recite the structure of optical gate; "all optical router", and "modulator" are indefinite and the claim fails to recite the structure of optical router and modulator; "photonic crystal is formed in active quantum well material" is indefinite; and "vertical cavity surface emitting lasers, VCSELS" is indefinite and the claim fails to recite the structure of vertical cavity surface emitting lasers.

Claim 5 -11 have been amended to recite the device in which the claimed array is used. The applicants respectfully submit that lasers, detectors, all-optical gates, all-optical routers, and modulators, active quantum wells and vertical

cavity surface emitting lasers, VCSELS are all well known existing photonic devices, which are clearly identified by those terms. These devices are known to include optical cavities or resonant elements. Claims 5 – 11 simply claim that the claimed array may be employed as the optical cavity or resonant element. In other words the claimed array may be combined or used in these devices.

Regarding claim 12, the Examiner objected to the phrase "a cubic half-wavelength" as indefinite because it was unclear to him what is "a cubic half-wavelength", and he further contended that the claim failed to recite size structure to define a cubic halt-wavelength. The nanocavity or simply defect in the pattern in the photonic crystal has a volume, since the crystal itself has a thickness. The light or electromagnetic wave propagates in the photonic crystal through its volume and not simply on the surface. Hence the defect or nanocavity has a volume. A defect that is one wavelength long (λ), one wavelength wide (λ) and one wavelength high (λ) would comprise a volume of one cubic wavelength(λ^3). This usage of language is common and well understood in photonics. A volume of one half of a cubic wavelength ($\lambda^3/2$) would be one half the volume of an object or, here a nanocavity, that was one wavelength long, one wavelength wide and one wavelength high.

Regarding claim 13, the Examiner regarded the phrase "array of lasers", nanocavity laser" and" pump for an adjacent nanocavity laser" as indefinite, and contended that the claim failed to recite a laser. Claim 13 has been responsively amended to positively recited the array of lasers. A laser is a well known photonic device and it is unnecessary to recite the structure of the laser in order

to identify it as a laser any more than it is necessary to recited the structure of an electronic component, such as a resistor or capacitor, in order to identify a device as a resistor or capacitor.

Regarding claim 14, the Examiner regarded the phrase " a nonlinear optical material filling said photonic crystal " as indefinite. A nonlinear optical material is well known. The application generically refers to nonlinear polymers or organic molecules. For example, there are 525 issued patents which use the identical phrase, "nonlinear optical material." U.S. Patent 6,577,591 states for example that "a material exhibiting an electrooptical effect is called a nonlinear optical material in some cases." A nonlinear optical material is a material whose optical properties are nonlinear, i.e. depend in a nonlinear manner on some variable. A material whose index of refraction varied nonlinearly based on the electric field imposed on the material would be a "nonlinear optical material." If the index of refraction of a material changed by the third root of the electric field strength, ($E^{1/3}$), it would be a nonlinear optical material. Claim 14 has been clarified to denote that filling the photonic crystal means filling the holes which serve to define the photonic crystal.

Regarding claim 15, the Examiner regarded the phrase "array is a tunable nanocavity laser, detector, router, gate or spectrometer array" as indefinite. Claim 15 has been responsive amended to clarify that the photonic device with the filled array comprises a tunable nanocavity laser, detector, router, gate or spectrometer array. Again, a tunable nanocavity laser, detector, router, gate or spectrometer array are all well known photonic devices.

Regarding claim 16, the Examiner regarded the phrase "means for changing optical or electrical properties of said nonlinear optical material " as indefinite because it is unclear what is "nonlinear optical material" and unclear to define how to provide optical or electrical. The basis of the Examiner's confusion is not well understood. The term, "nonlinear optical material" is described above. The specification states at page 4, beginning at line 20: "The array further comprises means for changing optical or electrical properties of the nonlinear optical material in each of the nanocavities, such as electrodes for applying a voltage or current across the array." The optical or electrical properties of the cavity, and the array as a whole, is changed when you apply an electric field to the array or pass a current through the array when the holes are filled with nonlinear optical material.

Regarding claim 17, the Examiner regarded the phrase "a cubic half-wavelength" as indefinite because it is unclear what is "a cubic half-wavelength" and contended that the claim failed to recite size structure to define a cubic halt-wavelength. These terms are not used in claim 17.

Regarding claim 18, the Examiner regarded the phrase "photonic crystals", and "in Si-Ge materials on silicon substrates disposed on insulators" as indefinite because it is unclear what is "photonic crystal" and contended that the claim failed to recite structure of laser. Claim 18 does not use these terms. Claim 17 uses the term, "photonic crystals", but does not refer to a laser. The term, "photonic crystal", is discussed above and is well known, being used in the identical form in 130 issued U.S. patents.

Claim 19 is definite for the reasons given in regard to claims 1, and 17.

Regarding claim 20, the Examiner regarded the phrase "a waveguiding layer disposed adjacent" as indefinite because it is unclear what is a "waveguiding layer" and contended that the claim recited no laser to define a waveguide. The inclusion of a waveguiding layer to the claimed combination does not require a laser in order for it to act as a waveguiding layer. A "waveguiding layer" is in photonics what a waveguide would be called in microwave technologies. The identical term is used in 185 issued U.S. patents and is discussed in detail beginning at page 13, line 19 et.seq.

Rejection Pursuant to 35 USC § 102

Claims 1 - 5, 7 - 14, and 16 - 20 were rejected as being anticipated by **Painter et al.,** Science Vol. 284. **Painter** was cited as disclosing a compact electrical and optically pumped multiwavelength nanocavity array comprising a plurality of nanocavities (See p 1819, column 3), each nanocavity defined in a photonic crystal (See p 1820, column 1) in which each nanocavity is lithographically formed to define a corresponding predetermined spectral response of each nanocavity, said plurality of nanocavities forming said array (See fig 1). The Examiner contended that a photonic crystal was formed in active quantum well material (See p 1820, column 2, first paragraph), that nanocavities were used in vertical cavity surface emitting lasers (see p 1919, column 3), that an array in a photonic crystal was formed in or with a silicon slab waveguide (See p 1820, column 1, second paragraph)

Painter, the prior work of the principal investigator, Axel Scherer, describes the fabrication of and performance of a single nanocavity. In regard to claim 1 what **Painter** does not teach and for which there is no disclosure whatsoever is an array of a plurality of such nanocavities, namely an array of subarrays of holes in each subarray of which is defined a nanocavity. **Painter** fails to teach a patterned array of nanocavities in any form and therefore cannot be held to teach each and every element of the claimed invention.

Painter does not teach an array comprising a plurality of nanocavities at p. 1819, column 3. A general reference is made to an interest in microcavities for spontaneous emission control, but no structure is discussed as claimed here. Fig. 1 of **Painter** shows a single nanocavity formed by the removal of one hole in the array of holes. There is no second nanocavity depicted nor any array of them. There is no discussion in **Painter** about predetermining the spectral response of a nanocavity, let alone of each of a plurality of nanocavities forming an array of nanocavities.

Claims 2 – 20 depend directly or indirectly on claim 1 and are further distinguished from **Painter** for the various additional limitations set forth in those claims, which are not disclosed by **Painter**. Claims 2 – 20 are directed to various aspect of an array of nanocavities. Since Painter is devoid of any disclosure regarding an array of nanocavities, it cannot be held to anticipate any aspect of an array of nanocavities.

Rejection Pursuant to 35 U.S.C. § 103

Claims 6 and 15 were rejected as obvious over **Painter,** which was cited as disclosing all of the limitations of compact electrically and optically pumped multiwavelength nanocavity array, but without any disclosure relating to a detector array. **Tanguary, Jr, et al**. was cited as disclosing the detector array (76a, 81 a) (See fig 11), such that it would have been obvious to modify **Painter** to have detector array as taught by **Tanguary, Jr**.

As discussed above, **Painter** is mischaracterized as disclosing an array of nanocavities. **Tanguary, Jr** is a photonic circuit in which optical detectors are employed, but otherwise has no connection or relevance to a nanocavity or an array of nanocavities. Any reference showing an optical detector would have been equally relevant as **Tanguary, Jr.** The combination of **Painter** and **Tanguary, Jr** do not result in any teaching relating to an array of nanocavities, since neither reference discloses or is directed to any aspect whatsoever of an array of nanocavities.

Further claims 6 and 15 depend directly or indirectly on claim 1 and are allowable therewith and for the additional limitations set forth in the subject claims.

The applicants do not believe that the prior art teaches or suggests any of the limitations of any of the claims. The amendments have been made only to be as responsive to the Examiner as possible to assuage any argument or concern for clarity of the claims, which the applicants respectively submit were sufficiently

clear and definite and met all minimum statutory conditions for patentability prior to amendment. The applicants respectfully request advancement of the claims to issuance.

Respectfully submitted,

Daniel L. Dawes
Reg. No. 27123
949 223 9600
fax 949 223 9610

Mailing Address:
Daniel L. Dawes
5252 Kenilworth Dr.
Huntington Beach, California 92649

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Nancy V. McElrath

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